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Associating object names with descriptions of shape that distinguish possible from impossible objects

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Five experiments examine the proposal that object names are closely linked to representations of global, 3D shape by comparing memory for simple line drawings of structurally possible and impossible novel objects. Objects were rendered impossible through local edge violations to global coherence (cf. Schacter, Cooper, & Delaney, 1990) and supplementary observations confirmed that the sets of possible and impossible objects were matched for their distinctiveness. Employing a test of explicit recognition memory, Experiment 1 confirmed that the possible and impossible objects were equally memorable. Experiments 2–4 demonstrated that adults learn names (single-syllable non-words presented as count nouns, e.g., "This is a dax") for possible objects more easily than for impossible objects, and an item-based analysis showed that this effect was unrelated to either the memorability or the distinctiveness of the individual objects. Experiment 3 indicated that the effects of object possibility on name learning were long term (spanning at least 2 months), implying that the cognitive processes being revealed can support the learning of object names in everyday life. Experiment 5 demonstrated that hearing someone else name an object at presentation improves recognition memory for possible objects, but not for impossible objects. Taken together, the results indicate that object names are closely linked to the descriptions of global, 3D shape that can be derived for structurally possible objects but not for structurally impossible objects. In addition, the results challenge the view that object decision and explicit recognition necessarily draw on separate memory systems, with only the former being supported by these descriptions of global object shape. It seems that recognition also can be supported by these descriptions, provided the original encoding conditions encourage their derivation. Hearing an object named at encoding appears to be just such a condition. These observations are discussed in relation to the effects of naming in other visual tasks, and to the role of visual attention in object identification.

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INTRODUCTION

Given that different types of visual representation have been distinguished, the question arises as to whether these are differentially associated with verbal information. For example, does one type of visual object representation have privileged links with object names?

Basic-level object representations

The concept of a basic-level visual representation emphasizes the significance of an intermediate level of structural description in object categorization (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Rosch et al. argue that this level of representation strikes an effective balance between maximizing the structural similarity of objects in the same category and minimizing the similarity of objects in different categories. Object shape is emphasized, rather than material and surface qualities, partly because the visual perceptual system is efficient at encoding this, but also because shape is a relatively reliable cue to object kind and object function (see, for example, Landau, Smith, & Jones, 1998). Regarding visual–verbal connections, Rosch et al. provide evidence for the special status of the link between basic-level representations of shape and object labels. They propose that these representations are associated with the most frequently used object names, which also happen to be the simplest object labels, the first to be acquired during development, and the most likely labels to be incorporated in languages with a limited object vocabulary (such, as American Sign Language—ASL).

Object naming and categorization

There is other evidence that object names, and count nouns in particular, are linked with visual representations of object shape that can accommodate variation in the appearance of an individual object and in the appearance of different objects from the same category (see Landau, 1994; Landau, Smith, & Jones, 1998, for reviews). When children and adults learn to associate a count noun with a novel object (e.g., "This is a dax"), they choose to generalize the name to other objects (e.g., "Which of these is a dax also?") on the basis of object shape rather than on the basis of material or surface qualities. The salience of shape in the extension of these object labels does not reflect an indiscriminate bias to group objects on the basis of shape, even for children, but is specific to situations in which count nouns are linked with objects (i.e., when objects are named). Thus, when objects are grouped in the absence of any object labels (e.g., "What goes with this?"), the shape bias is less apparent. Indeed, when objects are distinctively textured and the conditions of illumination highlight this, then labelling the objects with an adjective (e.g., "This is a daxy one") or a superordinate label (e.g., "This is a kind of dax"), can create a situation where generalization of a verbal label is based on material similarity rather than shape similarity (see Landau, 1994, for a review of the empirical evidence).

In these studies of object naming, object shape is considered to be more abstract than a 2D or 3D description that is specific to the conditions under which an object is viewed (i.e., shape is described in a way that is viewpoint independent). Furthermore, the concept of shape can accommodate the reconfiguration of non-rigid objects, as when a cat changes from a standing to a sitting position, or the lid of a box is opened. Thus, generalization of the name assigned to a novel object is not precluded by such reconfigurations of shape (see Landau, 1994).

Biederman (1987) argues that visual object recognition is based on a relatively abstract and largely viewpoint-independent description of an objects 3D shape. (The material and surface properties of objects are considered to contribute to object recognition only secondarily.) These structural descriptions are thought to capture all the primitive volumetric forms (geons) making up an objects overall shape, along with their spatial arrangement framed in object-based coordinates. In his experimental work, Biederman makes extensive use of a naming task on the understanding that object naming provides a relatively pure index of the contribution that these structural descriptions make to object recognition (see, for example, Biederman & Cooper, 1992). He and his colleagues find that priming effects in object naming generalize across variations in an objects appearance that result from changes in viewpoint (e.g., changes in picture size, spatial location, and angle of view) (see Biederman & Cooper, 1992; Biederman & Gerhardstein, 1993; Cooper, Biederman, & Hummel, 1992a).

Structural possibility and priming in object decision

A presemantic description of the global, 3D shape of an object has been isolated by contrasting peoples responses to pictures of possible and impossible novel objects (see Cooper, 1994; Cooper & Schacter, 1992, for reviews). Again, these structural descriptions are thought of as mental representations of an objects component parts and their object-based spatial arrangement, which together specify the objects global, 3D shape (e.g., Schacter et al., 1990). Depicted objects are rendered impossible by arranging for a picture to contain local surface and edge violations to complete coherence (see Figure 1 for examples of possible and impossible objects). In this way, qualitatively different effects from the two types of picture are attributed to the impact of a global, 3D shape representation, since it is the availability of this that distinguishes possible from impossible objects.[1]

It has been observed that priming in an object decision task (deciding whether a novel object is structurally possible or impossible) is confined to possible objects. This implies that priming reflects the impact of a description of

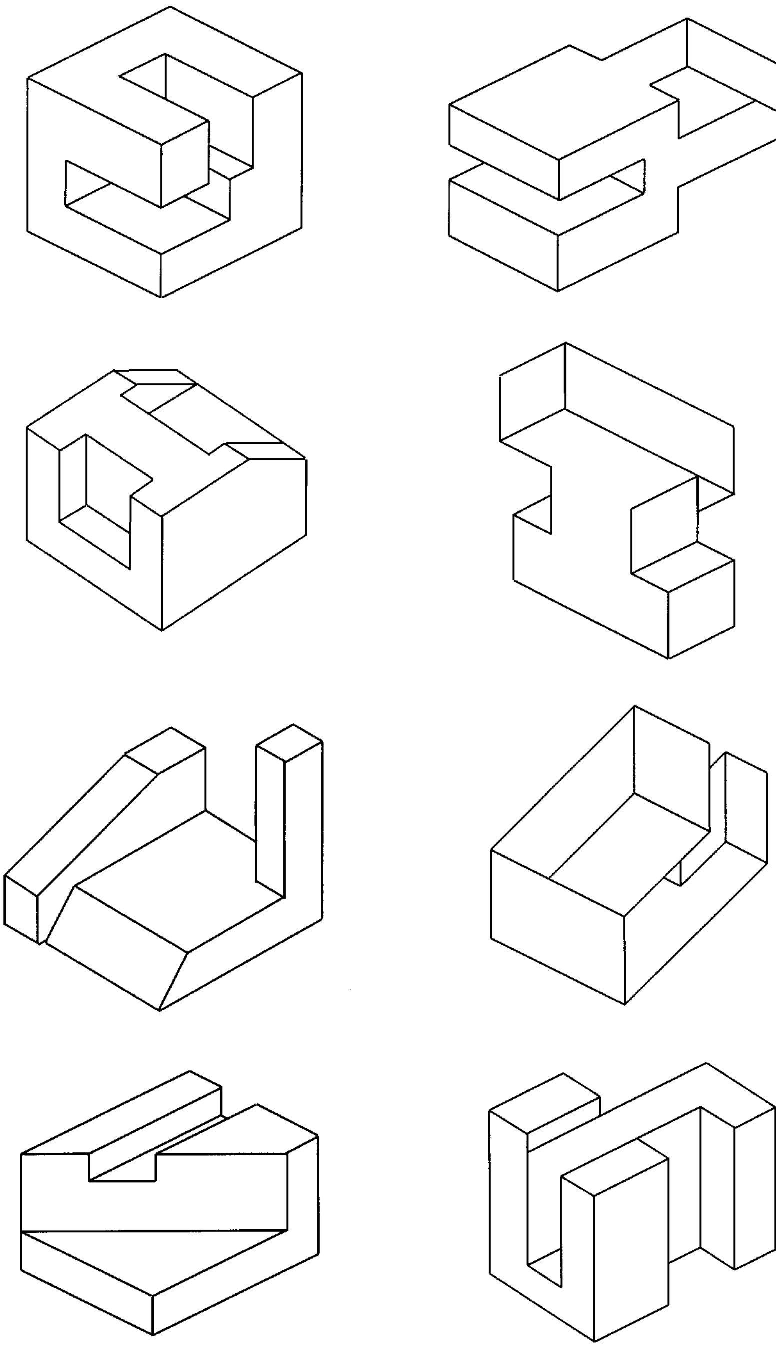

Figure 1. Examples of line drawings of possible and impossible objects used in the experiments.

the global, 3D shape of the priming object.[2] Converging evidence for this comes from the observation that such priming is contingent on the picture primes being encoded in a way that emphasizes the depicted objects global shape (Schacter & Cooper, 1993; Schacter et al., 1990). That the structural description is viewpoint independent is indicated by the observation that priming is equally strong whether study and test pictures depict an object from the same or from different viewpoints (Cooper et al., 1992b). Given its focus on structural information, coupled with its viewpoint invariance, the representation supporting object decision priming has been considered by Cooper, Schacter, Ballesteros, and Moore (1992b) to be the same representation supporting priming in Biederman's object naming task.

Recognition memory

The involvement of structural descriptions in object decision priming is contrasted with the involvement of quite different visual representations in explicit recognition memory (Cooper & Schacter, 1992). This contrast is evident in the stochastic independence of object decision and recognition for studied possible objects (Schacter et al., 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991a). In addition, a number of manipulations have been observed to influence explicit recognition, equally for possible and impossible objects, while at the same time having no impact on object decision. These manipulations include repeating the presentation of picture primes (Schacter et al., 1991a), adding functional and associative decisions to the encoding of picture primes (Schacter & Cooper, 1993; Schacter et al., 1991a), and introducing study-to-test differences in picture size (Cooper et al., 1992b). Interestingly, Biederman and Cooper (1992) also found that study-to-test changes in size affected explicit recognition memory without impacting at all on object naming.

This evidence suggests that object naming and object decision both rely on the same representation of object shape, whereas explicit recognition is supported by other representations. However, the nature of these other representations remains largely unspecified. Given the general equivalence of recognition for possible and impossible objects, in terms of absolute levels of performance and sensitivity to a range of manipulations, these other representations would appear to be less global than the shape descriptions underlying object naming and object decision. Rather, they appear to preserve information about the more localized visual features incorporated in depictions of possible and impossible objects. In addition, of course, they have been shown to preserve information about size and parity, and are assumed to incorporate visual details indicative of an objects material and surface qualities (such as colour and texture).

The present study

These different lines of enquiry suggest that a view-independent visual representation of the global, 3D shape of an object is closely linked with representation of its category name. Although comparing memory for pictures of possible and impossible objects has served to isolate this form of visual representation in the object decision task, the same comparison has not been made in relation to object naming. The present study is a first attempt to manipulate object possibility to examine the link between visual representation of global, 3D shape and representation of object name. The main task devised for this purpose (Experiments 2–4) requires adults to learn nonsense names, in the form of count nouns, to pictures of possible and impossible novel objects. It is predicted that object names will be learned more easily to pictures of possible objects than to pictures of impossible objects. It is assumed that there will be some learning of names for impossible objects, because there are other bases on which picture–name associations can be learned, as when people learn names for visual features such as colour. However, the argument is that object names will be learned more easily to pictures of possible objects because support can be derived from the normally close links between representations of global, 3D object shape and object names.

The present study also examines the impact on recognition memory of hearing an object named at encoding (Experiment 5). More specifically, it tests the proposal that global structural possibility can influence recognition memory and will do so when objects are named at encoding. Previous research has shown that priming, and therefore an effect of object possibility, is not always observed in the object decision task (Schacter et al., 1990). Thus, priming has been observed when participants have had to indicate whether each priming object faced left or right, but not when they have had to say if it contained more vertical or horizontal edges. It would appear that deriving a structural description of an objects overall shape is not obligatory and is partly determined by the encoding instructions. It is possible, therefore, that in previous studies of recognition memory object possibility has generally failed to have an effect, not because structural descriptions are incapable of supporting recognition memory, but because the encoding tasks have not made 3D object shape a salient feature. To test the idea that representations of global, 3D shape and name are closely linked, it is determined if hearing the experimenter name an object at encoding with a count noun will ensure that object possibility has an impact on recognition memory.

EXPERIMENT 1

Before determining if verbal labels are more easily learned to pictures of possible objects than to pictures of impossible objects, it was considered important to ensure that there was no effect of object possibility on recognition memory for the pictures themselves. The absence of such an effect would offer reassurance that the two types of picture were matched in terms of their own memorability. Any effect of object possibility on the ease with which object names are learned could then be related specifically to the shape–name associations.

In an *incidental* memory condition, recognition memory for the pictures was examined when participants had no expectation that their memory for the pictures would be tested. It was considered that this would minimize the likelihood that verbal recoding and elaboration would be used to facilitate remembering, on the assumption that these are intentional processes (see, Baddeley, 1990, for evidence, reviewed in the context of the working memory framework, that verbal recoding of to-be-remembered visual items is intentional). In this way, incidental recognition memory was used as a relatively pure measure of the visual memorability of the pictures. It was expected that object possibility would have no effect, confirming the equivalence of the two sets of pictures. In an *intentional* memory condition, recognition memory for the pictures was examined when participants were forewarned that their memory would be assessed. No attempt was made to encourage participants to adopt any specific strategies for remembering, verbal or otherwise. The inclusion of this condition permitted comparison with previous studies in which object possibility failed to influence intentional recognition memory (e.g., Cooper et al., 1992b, Exp. 1; Schacter et al., 1991a).

Method

Participants. Eighty undergraduate students at Lancaster University participated in the experiment. Forty students were randomly assigned to the incidental and intentional memory conditions, with the constraint that the same number of male (and female) participants took part in each condition.

Materials. Twenty-four black-on-white line drawings were created using Macromedia Freehand (version 5.0) on a Power Macintosh 8500/120. They were printed on a LaserWriter Pro printer and laminated to form 12.5 × 9.5cm cards. The objects were scaled in the picture so that their maximum dimension, horizontal or vertical, was approximately 6cm, with individual variation permitted to give the impression the objects were the same size. The twelve possible objects and four of the impossible objects were based on those illustrated by Lynn Cooper and Daniel Schacter in their various publications. New pictures of impossible objects were created by one of the authors (PW). Eight of the pictures are illustrated in Figure 1. A duplicate set of 24 cards was produced for testing recognition memory. Different sets of cards were prepared for the study and test phases of the task in order to prevent participants from capitalizing on any distinguishing features in the picture cards themselves (such as a blemish in the lamination or a bent corner).

Design. A mixed design was employed, with Memory Condition (incidental versus intentional) as a between-participants factor, and Object Possibility (possible versus impossible objects) as a within-participants factor.

Preliminary work revealed that setting the number of to-be-remembered pictures at 10 yielded intermediate levels of task performance that avoided floor and ceiling. For each trial, therefore, 10 possible and 10 impossible objects were randomly selected from the pool of 24 pictures. From this set of 20 pictures, five possible and five impossible objects were selected at random. A random order for their presentation was determined, with the constraint that no more than two successive presentations involved the same type of object. Each ordering for a set of to-be-remembered pictures, as well as the reverse ordering, was used once in each memory condition.

Procedure. All participants were told that the researchers were interested in arithmetic, and specifically in the way that people speeded up across successive practice periods. It was explained that they would be required to complete as many addition problems as possible in two, 2-minute spells. These were to be separated by a period in which they would be engaged in unrelated activity.

After the first period of arithmetic all participants completed the visual memory task. Those in the incidental condition were told that the experimenter wanted them to look at some unrelated material in order to prevent them from thinking about, and visualizing, any of the arithmetic problems they had just completed. They were instructed simply to look at the sequence of pictures, and it was explained that after doing so they would undertake a second period of paced arithmetic. Participants in the intentional condition were told that the experimenter was also interested in testing their visual memory, and for this reason they were being asked to look at a sequence of 10 pictures. They were given a brief indication of the manner in which their memory would be tested.

The experimenter placed the 10 to-be-remembered pictures on a table in front of the participant. A computer metronome synchronized the placement of successive cards, on top of each other, at a 2sec rate. After presentation of the sequence of to-be-remembered pictures, all 20 pictures selected for that trial were displayed on the table. The sets of possible and impossible objects were arranged separately, each in two columns of five pictures. Participants were required to select the five possible and five impossible objects they had just seen. They alternated their selections across the two object types, with half the participants in each condition choosing a possible object first, and half choosing an impossible object first. A second spell at arithmetic did not take place and participants completed just one trial.

After completion of the experiment, participants in the incidental memory condition were asked if they had anticipated that their memory for the pictures would be tested. The plan was to replace any participant who did anticipate being tested, but in the event this was not necessary.

Results

Table 1 presents the mean number of possible and impossible objects correctly recognized in the incidental and intentional memory conditions. A 2 (Object Possibility) × 2 (Memory Condition) analysis of variance (ANOVA) revealed a significant effect of memory condition, $F(1, 78) = 5.65$, $p = .02$, with more pictures correctly recognized in the intentional memory condition. Object possibility failed to have a significant effect on recognition, $F(1, 78) = 0.28$, $p = .60$, and did not interact significantly with memory condition, $F(1, 78) < 1$.

An item-based analysis was undertaken on the number of participants correctly recognizing each of the 24 pictures. Memory condition failed to have a significant effect, $F(1, 44) = 2.24$, $p = .14$. The main effect of object possibility and its interaction with memory condition were also insignificant, $F(1, 44) = .001$, $p = .98$, and $F(1, 44) < 1$, respectively. That the memorability of the individual pictures had been measured with some reliability was indicated by a significant correlation in item memorability across the incidental and intentional memory conditions, $r = .41$, $p < .05$.

Because of the importance of the null result regarding object possibility, it was determined if Experiment 1 was powerful enough to provide sufficient protection against a Type II error (see Keppel, Saufley, & Tokunaga, 1992, for an explanation of the procedures for relating indices of power, effect size, and sample size). If it is assumed that there is an underlying effect of object possibility of moderate size ($\omega^2 = .06$), then 54 participants would be required to yield an acceptable value of .80 for power. In Experiment 5, reported later, explicit recognition memory for the same set of pictures was assessed in the same way as in Experiment 1. In one condition, where the pictured objects were named by

TABLE 1
Experiment 1: Mean number of possible and impossible objects correctly recognized by a participant as a function of the incidental versus intentional nature of remembering

	Object Type	
Memory Condition	*Possible*	*Impossible*
Incidental	3.58	3.70
Intentional	3.98	3.98

Maximum score = 5, chance = 2.5.

the experimenter at encoding, a significant effect of object possibility was observed. Based on the value of F associated with this significant result, the effect of object possibility is seen to be very large, $\omega^2 = .25$, and if this value is applied to Experiment 1, it emerges that 12 participants would be required to yield a value for power of .08. In summary, from these considerations of effect size and power, it seems that with 80 participants in Experiment 1 there was power to provide sufficient protection against a Type II error. This issue is revisited in the context of Experiment 5, where additional results are combined with those from Experiment 1 to provide an even more powerful test of the null effect of object possibility.

Supplementary observations

A new group of 15 participants, drawn from the general student population at Lancaster University, provided information on the distinctiveness of the 24 objects in order to determine if this feature was confounded with object possibility. They were each given a 132-page booklet containing all possible pairings of objects from the same category (possible and impossible). The black-on-white line drawings were reproduced exactly as for Experiment 1, and the pairs of pictures appeared in a random order, except for the constraint that no more than two successive pages involved pictures from the same category. Two alternative booklets were prepared, differing with regard to the order in which the picture pairs appeared. To each picture pair participants assigned a rating from –4 (dissimilar) to 4 (similar), on a 9-point scale, indicating the degree to which they judged the two objects to be visually dissimilar/similar to each other. Participants were asked to flip through the booklet to appreciate the nature and variability of the picture pairs. They were then asked to make their judgements of dissimilarity/similarity relative to the total set of 132 picture pairs.

Ratings of the picture pairs. Across all participants, an average rating for each of the 132 picture pairs was determined. The overall means for pairs of possible and impossible objects were – 0.63 and – 0.55, respectively, a difference that proved to be insignificant by ANOVA, $F(1, 130) < 1$.

Ratings of individual objects. For each of the 24 objects, an average rating was derived from each participants ratings of all the picture pairs in which it was involved. These average ratings were submitted to an ANOVA with objects as a within-participants factor. The main effect of object was significant, $F(23, 322) = 4.11$, $p < .001$, indicating that the rating procedure had measured the distinctiveness of the objects with some reliability. A planned comparison confirmed that the difference in the average rating of possible and impossible objects was not significant, $F(1, 14) = 0.06$, $p = .81$. When the ratings of distinctiveness for the 24 objects were correlated with the memorability scores obtained in Experiment 1, the relationship proved to be insignificant, $r = .26$, $p > .10$.

Discussion

Telling participants in advance that their memory would be tested enhanced recognition memory for the pictures, equally so for possible and impossible objects. This enhancement could reflect the impact of some global aspect of processing, such as an increase in the overall level of resources allocated to the task. Alternatively, it could reflect a qualitative shift towards relying on particular processes and representations. For example, knowing that their memory was to be tested, participants could have related the pictures to familiar objects they resembled. It has already been noted that adding functional and associative decisions to the encoding of picture primes enhances recognition memory, and does so equally for possible and impossible objects (Schacter & Cooper, 1993; Schacter et al., 1991a). Whatever qualitative shift in processing might underpin the enhanced levels of recognition, however, it is clear from the results of Experiment 1 that it does not involve a greater reliance on representations of global 3D shape, since such a shift would favour pictures of possible objects over pictures of impossible objects.

Previous studies have occasionally failed to find an effect of object possibility on intentional recognition memory, even when there has been an effect on object decision (e.g., Cooper et al., 1992b, Exp. 1; Schacter et al., 1991a). Experiment 1 has shown that this insensitivity to object possibility can extend to incidental as well as intentional remembering. In the light of the power of this experiment to detect an effect of object possibility, these null results offer reassurance that the present sets of pictures are matched with regard to their individual memorability (see also the results of Experiment 5 later, where incidental recognition memory for these pictures again failed to show an effect of object possibility). In addition, the supplementary observations indicate that the two sets of pictures were also matched regarding their visual distinctiveness. If it is now found that object possibility influences the ease with which names for novel objects are learned, then this can be attributed with greater confidence to the task of associating object shape with object name.

EXPERIMENT 2

The issue of whether object names are more easily learned to pictures of possible objects than to pictures of impossible objects was addressed directly in Experiment 2. The presentation of each picture was accompanied by a spoken nonsense syllable in the context of a sentence frame that assigned it the role of a count noun (e.g., "This is a dax."). Participants were requested to learn the non-word associated with each picture, so that when subsequently presented with a picture they could recall the corresponding non-word.

Participants. Forty undergraduate students at Lancaster University participated in the experiment. None had participated in Experiment 1.

Materials. The 24 pictures utilized in Experiment 1 (12 possible and 12 impossible objects) were also used in Experiment 2. In addition, 24 single-syllable non-words were generated to serve as verbal labels for the pictures (cf. Table 2).

Design. A within-participants design was employed, with object type and trial number as the two factors. Each participant was exposed to two types of object (possible and impossible) on each of four successive learning trials. Memory for each picture–non-word association was assessed on every trial.

Procedure. A random order of presentation for the 24 pictures was determined for each participant, with the constraint that no more than two successive presentations involved an object from the same category. This order was used in the learning phase on all four trials. In this phase the experimenter presented each picture for 5sec and at the same time gave a spoken verbal label to be associated with it. Every verbal label incorporated a different one of the non-words, presented in a standard sentence frame that assigned to it the function of a count noun (e.g., "This is a dax.", "This is a rif."). The 24 non-words were randomly assigned to the pictures, differently for each participant, and the pairings were fixed across all four trials. After presentation of the picture–label pairs, the pic-

TABLE 2
The single syllable non-words to be associated with the possible and impossible objects

Dax	Nid
Rif	Rin
Dep	Vob
Bax	Lum
Sif	Nop
Geb	Tol
Kiv	Ruv
Fob	Mit
Bal	Wib
Bav	Wut
Zib	Zal
Gef	Lef

tures were randomly re-ordered for the test of memory. The experimenter re-presented each picture in turn and asked for the associated non-word. Participants were permitted to offer no response if they could not recall the non-word, but when a response was offered no feedback was provided regarding its correctness. There was no pressure on participants to respond within a certain time. The next trial started with another learning phase in which the pictures were again presented with their verbal labels. A further test phase followed in which the pictures were presented in a fresh random order. Each participant completed a total of four trials.

Results

Table 3 presents the mean number of names correctly recalled by a participant as a function of object type and trial number.

Performance improved across successive trials, as one would expect. In addition, from trial 1 through to trial 4, the names of possible objects were recalled better than the names of impossible objects. A 4 (Trial Number) × 2 (Object Possibility) ANOVA confirmed the significance of trial number, $F(3, 117) = 157$, $p < 001$, and object possibility, $F(1, 39) = 27.0$, $p < 001$. The interaction between these two factors was not significant, $F(3, 117) = 2.34$, $p = .07$. Tests of simple effects showed that object possibility had a significant effect on every trial, $F(1, 39) = 9.96$, 18.25, 14.45, and 12.52, for trials 1 to 4, respectively, $p < 005$ in all cases.

An item-based analysis was undertaken on the average number of trials (max. = 4) on which the name of each picture was correctly recalled by a participant. The overall means were 1.5 and 1.13 for possible and impossible objects, respectively. The effect of object possibility was significant, $F(1, 22) = 4.78$, $p <$ .04. This effect remained when the memorability and distinctiveness of the 24 items (see Experiment 1) were treated as covariates, $F(1, 21) = 4.78$ and 4.62, respectively, $p = .04$ in both cases. A second item-based analysis was undertaken on the number of participants correctly recalling the name of each picture on each of the four trials. The average number of participants recalling the name of a possible object on an individual trial was 15.17. The average number

TABLE 3
Experiment 2: Mean number of names recalled by a participant as a function of object type and trial number (max. score = 12)

	Trial Number			
Object Type	*1*	*2*	*3*	*4*
Possible	1.10	3.47	5.97	7.60
Impossible	0.52	2.00	4.67	6.37

of participants recalling the name of an impossible object on an individual trial was 11.29. An ANOVA, with possibility as a between-items factor and trial as a within-items factor, confirmed the significance of both the effect of object possibility, $F(1, 22) = 5.18$, $p < .04$, and the effect of trial, $F(3, 66) = 296$, $p < .001$. Although the overall interaction between object possibility and trial was not significant, $F(3, 66) = 1.71$, $p = .17$, analysis of simple effects revealed that object possibility had an effect on all trials except the first, $F(1, 36) = 0.89$, 6.46, 5.22, 5.02, with $p = .35$, .01, .03, .03, for trials 1 to 4, respectively. Once again, the main effect of object possibility remained when item memorability and distinctiveness were treated as covariates, $F(1, 21) = 5.14$ and 5.13, respectively, $p < .04$ in each case.

Discussion

Names can be learned more easily to pictures of possible objects than to pictures of impossible objects, consistent with the idea that names are closely linked with descriptions of the overall, 3D shapes of objects. Since the results of Experiment 1 confirmed that the two types of picture were themselves equally memorable and equally distinctive, and since the non-words were randomly assigned to the pictures, the different levels of name learning across the two types of picture appear to reflect aspects of the association between object shape and object name.

EXPERIMENT 3

Participants in Experiment 2 found themselves in a rather artificial situation, being asked to learn associations between visual and verbal items that had little relevance to the real world and which they assumed would not be encountered again. It is possible, therefore, that the learning observed across the four trials of Experiment 2 reflects the involvement of special purpose mechanisms, specifically and temporarily established for the experimental task. The learning might not reflect processes normally supporting the long-term learning of object names, and the observed impact of object possibility might have no bearing on the organization of long-term knowledge about objects and their names.

Two months after Experiment 2 was run, the opportunity arose to re-test 16 of the original participants, to determine if there was still some retention of the shape–name associations and, if so, if the effect of object possibility was still apparent. The participants had no expectation that they might be approached to take part in a further study and had not, therefore, taken any steps to rehearse the shape–name associations encountered in Experiment 2.

Method

Participants. Sixteen of the original participants were recruited two months after taking part in Experiment 2. Their availability was not under the control of the researchers, but was determined by a mix of circumstances unrelated to the purpose of the study.

Materials. The materials prepared for Experiment 2 were used again, and for each participant the original shape–name associations were retained.

Design and procedure. Essentially the same design and procedure were adopted as for Experiment 2. The one modification involved dispensing with the study phase on the first of the four trials completed by each participant. Thus, the experiment started with a testing phase to assess the extent to which participants could still recall the name associated with each picture. Thereafter, the remaining three trials were completed in the same way as for Experiment 2. In the study phase the experimenter presented each picture along with its associated non-word. In the testing phase each picture was presented in turn, in a fresh random order, and participants were requested to recall the associated non-word. As before, no feedback was provided regarding the correctness of a response.

Results

Table 4 presents the mean number of non-words correctly recalled as a function of object possibility and trial number. The results from Experiment 2 for the same 16 participants are also presented.

TABLE 4
Mean number of names recalled by a participant as a function of experiment, object type, and trial number for participants taking part in both experiments (max. score = 12)

	Trial Number			
Object Type	*1*	*2*	*3*	*4*
Experiment 2				
Possible	1.00	2.56	4.94	6.75
Impossible	0.37	1.31	3.50	5.31
Experiment 3				
Possible	1.94	5.56	7.44	8.56
Impossible	1.12	4.44	6.19	8.19

Performance is consistently superior in Experiment 3, indicating that over the 2-month period between the experiments some information about the original shape–name associations had been retained. Not only does there appear to be savings in relearning the shape–name associations across trials 2 to 4, but performance on trial 1 of Experiment 3 is better than performance on trial 1 of Experiment 2. Performance also improves across successive trials and the names of possible objects are recalled better than the names of impossible objects on every trial in each experiment.

A 2 (Experiment) × 4 (Trial Number) × 2 (Object Possibility) ANOVA revealed significant main effects of experiment, $F(1, 15) = 25.91$, $p = .0001$, trial number, $F(3, 45) = 71.42$, $p = 0$, and object possibility, $F(1, 15) = 22.49$, $p = .001$. The interaction between experiment and trial number was significant $F(3, 45) = 9.24$, $p = .0001$, but no other interactions approached significance.

Separate ANOVAs were also undertaken for each experiment. For Experiment 2, the main effect of trial number was significant, $F(3, 45) = 45.4$, $p = 0$, as was the main effect of object possibility, $F(1, 15) = 18.36$, $p = .0001$. The interaction between these two factors was not significant, $F(3, 45) = 1.23$, $p = .31$. Analysis of simple effects confirmed that object possibility had a significant effect on every trial, $F(1, 15) = 6.82$, 8.33, 6.89, and 16.57, for trials 1 to 4, respectively, $p < .025$ in all cases. A similar pattern of significant effects was confirmed for Experiment 3. The main effect of trial number, $F(3, 45) = 72.64$, $p = 0$, and the main effect of object possibility, $F(1, 15) = 10.16$, $p < .01$, were both significant. The interaction between these effects was not significant, $F(3,45) = 1.44$, $p = .24$. Analysis of simple effects revealed that object possibility had a significant effect on each of trials 1 to 3, but not on trial 4: $F(1, 15) = 8.59$, $p = .01$; $F(1, 15) = 19.29$, $p = .001$; $F(1, 15) = 5.6$, $p = .032$; and, $F(1, 15) = 0.68$, $p = .42$, respectively.

Finally, a 2 (Experiment) × 2 (Object Possibility) ANOVA was undertaken for the first trial of both experiments. The main effect of experiment was significant, $F(1, 15) = 4.46$, $p = .05$, as was the main effect of object possibility, $F(1, 15) = 16.57$, $p = .001$. The interaction between these two factors was not significant, $F(1, 15) < 1$. Simple effects analysis confirmed that object possibility had a significant impact on performance in both Experiment 2 and Experiment 3, $F(1, 15) = 6.82$ and 8.59, respectively, $p < .025$ in each case.

Discussion

Two months after their involvement in Experiment 2, participants showed some retention of the shape–name associations they had learned, and the effect of object possibility was still in evidence. Participants had not anticipated having their memory tested again. Therefore, the results encourage the view that the learning in Experiment 2 reflected processes normally associated with the long-term learning of object names, rather than with special purpose processes established temporarily for the specific task at hand.

EXPERIMENT 4

Experiment 4 replicated Experiment 2 except for the manner in which memory for the shape–name associations was tested. Instead of presenting a picture and asking participants to recall the associated name, the picture–name association was tested in the reverse direction. The experimenter presented each name (by saying, for example, "Which is the dax?") and asked participants to pick out the associated picture from the total set of 24 displayed on the table in front of them. As in Experiment 2, a different random order of testing the name–picture associations was used on each of the four trials.

Method

Participants. Twenty undergraduate students at Lancaster University participated in the experiment. None had participated in the preceding experiments.

Materials, design, and procedure. These were the same as for Experiment 2, with participants again completing four trials, each comprising a study and test phase. The one procedural difference related to the way in which memory for the shape–name associations was tested. At the beginning of each test phase, the experimenter displayed all 24 cards on the table in front of the participant in a random arrangement. She then presented each non-word within the context of a sentence frame that asked participants to point out the associated picture (e.g., "Which is the dax?").

Results

Table 5 presents the mean number of objects correctly identified by a participant as a function of object type and trial number.

TABLE 5
Experiment 4: Mean number of objects correctly identified by a participant as a function of object type and trial number (max. score = 12)

	Trial Number			
Object Type	*1*	*2*	*3*	*4*
Possible	2.75	4.45	6.40	8.00
Impossible	2.20	4.10	5.60	7.30

Performance improved across successive trials, as one would expect. In addition, on all four trials pictures of possible objects were more often correctly identified than were pictures of impossible objects. A 4 (Trial Number) × 2 (Object Possibility) ANOVA confirmed the significance of trial number, $F(3, 57) = 82.03$, $p < .001$, and object possibility, $F(1, 19) = 6.87$, $p < .02$. The interaction between these two factors was not significant, $F(3, 57) < 1$. Tests of simple effects showed that object possibility failed to have a significant effect on trials 1 and 2, $F(1, 19) = 1.24$, $p = .28$, and $F(1, 19) = 0.54$, $p = .47$, respectively. However, on trials 3 and 4 the effect of object possibility was significant, $F(1, 19) = 4.75$, $p < .05$, and $F(1, 19) = 6.60$, $p < .02$, respectively. In contrast with Experiment 2, a significant effect of object possibility was not observed on all four trials, and the less robust nature of the effect meant that it did not emerge as a significant factor in an item-based analysis. It is not clear why this should be so, though the procedure might be seen to hold potential for more interference during memory retrieval (participants needed to scan the set of 24 pictures after being given a name, even if they could recall the corresponding picture without looking for it, and this may be more prone to interference than retrieving a name in response to the presentation of a single picture).

Discussion

A possible objects coherent, 3D structure makes it easier to learn its name, even when this is tested in the reverse direction, i.e., when people select a pictured object in response to hearing a name. Of course, adopting a *procedure* that probes the association in the reverse direction does not guarantee that the underlying representations were also accessed in the reverse direction. It is conceivable, for example, that after hearing a name probe, participants looked at each picture in turn, retrieved its name, and then compared this against the name probe offered by the experimenter. Although further work is needed to reveal the way underlying processes differ according to task instructions, the present results do suggest that the privileged link between global, 3D shape and object name will impact on behaviour in a variety of situations.

EXPERIMENT 5

Previous studies have been interpreted as demonstrating that object decision and recognition can draw on separate visual representations (see Cooper & Schacter, 1992). The dependence of object decision performance exclusively on structural descriptions of the global, 3D shapes of objects is understandable given the nature of the information on which the decisions have to be made. Confirmation of this comes from the observation that priming is confined to possible objects and to situations in which the encoding task requires attention to be focused on the global shapes of the objects (Schacter et al., 1990). More generally, however, the stochastic independence of object decision and recognition for previously studied possible objects is indicative of the absence of shared processes (Schacter et al., 1990, 1991a). Finally, object decisions have proven insensitive to a range of manipulations that influence recognition memory (Cooper et al., 1992b; Schacter & Cooper, 1993; Schacter et al., 1991a).

The idea that recognition can utilize representations other than those supporting object decision also receives some support (Cooper & Schacter, 1992). Apart from the stochastic independence of the two types of decision, there have been occasions when object possibility has had little or no impact on recognition memory, despite having a big impact on object decision (see, for example, Cooper et al., 1992b, Exp. 1; Schacter et al., 1991a). In addition, particular changes in the encoding instructions have been seen to eliminate priming in the object decision task, while at the same time enhancing recognition memory for the same objects (Schacter et al., 1990).

Given the nature of the information on which object decisions have to be made, the claim that they rely exclusively on structural descriptions of global, 3D shape would seem a reasonable one. However, the idea that recognition memory relies exclusively on other representations, and not at all on the representations underpinning object decisions, is not so easy to explain. One explanation might start with the premise that structural descriptions can contribute to implicit remembering (e.g., priming) but not to explicit remembering (e.g., recognition) (Cooper & Schacter, 1992; Schacter et al. 1990). Support for this premise has been drawn from the fact that amnesic patients show normal levels of priming in the object decision task (Schacter, Cooper, Tharan, & Rubens, 1991b). However, appealing to the general distinction between implicit and explicit remembering introduces its own uncertainties. For example, it is unclear why, in principle, a structural description system could not contribute to explicit remembering. Indeed, although there have been occasions when object possibility has had little or no effect on recognition memory, despite having a big impact on object decision, (see, for example, Cooper, Schacter, Ballesteros, & Moore, 1992, Exp. 1; Schacter et al., 1991a), there have been other occasions when it has had a consistent and significant effect on recognition memory (see, for example, Schacter & Cooper, 1993). Furthermore, in Experiments 2 and 3 of the present study, an effect of object possibility was observed in a test of explicit remembering, albeit a test that focused on memory for object–name associations rather than on memory for the objects themselves. Indeed, Cooper, Schacter, Ballesteros, and Moore (1992, p. 54) acknowledge that object possibility can influence explicit recognition memory. They propose that any source of information that can distinguish to-be-remembered items, including structural descriptions recoverable from possible objects, can support episodic retrieval processes, provided these sources of information were part of the conditions under which the items were originally encoded. The final experiment to be reported explores this issue in relation to shape–name associations.

Experiment 1 failed to reveal an effect of object possibility on recognition memory, whether or not participants were forewarned that their memory would be tested. However, in previous studies, object-decision priming and the accompanying effects of object possibility have been observed only when the encoding instructions have directed participants' attention to the global shape of each object (e.g., Schacter et al., 1990). Thus, priming of possible objects has been observed when participants have indicated whether each priming object faced left or right, but not when they have said if it contained more vertical or horizontal edges. It would appear, therefore, that deriving a structural description of an objects overall shape is not obligatory, and is partly determined by the encoding instructions. In turn, therefore, object possibility might influence recognition only when the encoding instructions ensure the salience of the global shape of each object.

Evidence was reviewed in the Introduction suggesting that representations of the global, 3D shapes of objects have privileged links with their names. So that, for example, naming objects at presentation draws peoples attention to object shape, with the result that the objects are categorised according to their shape and their names are extended to new objects on this basis (Landau, 1994). Experiment 5 examines incidental and intentional memory for pictures of objects in the manner of Experiment 1, but incorporates a condition in which the objects are named by the experimenter as they are presented in the study phase. In this way the experiment tests two ideas. First, hearing a pictured object named at presentation will increase the likelihood that a representation of its global, 3D shape is derived. Second, such a representation will support recognition memory for the picture. Therefore, in the condition where objects are named at presentation, it is predicted that recognition memory will be superior for pictures of possible objects compared with pictures of impossible objects. By contrast, in the condition where objects are not named at presentation, it is predicted that recognition memory will be equivalent for possible and impossible objects, as was observed in Experiment 1.

Method

Participants. Eighty undergraduate students at Lancaster University participated in the experiment. None had participated in any of the previous experiments. Twenty students were randomly assigned to each of the four conditions obtained by crossing two factors—Naming (no-naming versus naming) and Memory Condition (incidental versus intentional remembering)—with the constraint that the same number of male (and female) participants took part in each condition.

Materials. Pictures of 10 possible and 10 impossible objects were selected at random from the pool of pictures used in Experiment 1. Similarly, 20 of the single-syllable non-words generated for Experiment 2 were selected at random for use here.

Design. A mixed design was employed, with Naming and Memory Condition as between-participants factors, and Object Possibility as a within-participants factor. For each trial, five possible and five impossible objects were selected at random from the set of 20 pictures. For the naming condition, 10 of the non-words were randomly selected from the pool of 20 and randomly assigned for each participant to the 10 to-be-remembered pictures.

Procedure. The procedure was essentially the same as for Experiment 1, with arithmetic again providing a cover story in the incidental memory condition to hide the fact that recognition memory for the pictures was to be tested. For the no-naming condition the same procedure was used as for Experiment 1. The only difference for the naming condition was that the experimenter named each picture as it was presented during the study phase. The non-words were embedded in a sentence frame that gave them the role of a count noun (e.g., "This is a dax.").

After presentation of the sequence of to-be-remembered pictures, all 20 pictures selected for that trial were displayed on a table in front of the participant. In the naming condition no mention was made of the names that had been associated with the objects during the study phase. Rather, participants were requested simply to identify the pictures they had seen earlier.

Participants completed just one trial and in the incidental memory condition they were asked if they had anticipated the memory test. In the event, this was not anticipated by any of the participants.

Results

Table 6 presents the mean number of possible and impossible objects correctly recognized by a participant as a function of the naming and memory conditions. For the no-naming condition, the results replicate those obtained in Experiment 1. Although recall is generally enhanced by an intention to remember, it is not influenced by object possibility. For the naming condition, the pattern of results is different. Although there is again a general increase in recall with an intention to remember, there is now an effect of object possibility, with structurally possible objects being better recalled than impossible objects. A 2 (Naming Condition) × 2 (Memory Condition) × 2 (Object Possibility) ANOVA revealed significant main effects of memory condition, $F(1, 76) = 14.01$, $p < .001$, and object possibility, $F(1, 76) = 12.27$, $p < .001$. Although the main effect of naming was not significant, $F(1, 76) < 1$, its interaction with object possibility

TABLE 6
Experiment 5: Mean number of possible and impossible objects correctly recognized by a participant as a function of whether or not objects were named at study, and whether remembering was incidental or intentional

		Object Type	
Naming Condition	*Memory Condition*	*Possible*	*Impossible*
No-naming			
	Incidental	2.85	2.80
	Intentional	3.60	3.55
Naming			
	Incidental	3.30	2.50
	Intentional	3.60	2.90

Maximum score = 5, chance = 2.5.

was significant, $F(1, 76) = 9.39$, $p < .01$. Analysis of simple effects confirmed that object possibility influenced memory in the naming condition, $F(1, 76) = 21.56$, $p < .001$, but not in the no-naming condition, $F(1, 76) < 1$.

An item-based analysis was undertaken on the number of participants correctly remembering each of the 20 items. After collapsing the data across the incidental and intentional memory conditions, an ANOVA was completed with object possibility as a between-items factor and naming as a within-items factor. Although the main effects of naming and object possibility were not significant, $F(1, 18) < 1$, and $F(1, 18) = 1.34$, $p = .26$, the interaction between these factors was marginally significant, $F(1, 18) = 4.06$, $p = .06$. Analysis of simple effects confirmed that, whereas object possibility had no effect on memory in the no-naming condition, $F(1, 18) < 1$, it had a significant effect in the naming condition, $F(1, 18) = 5.82$, $p < .03$.

Finally, except for the fact that a fixed sub-set of 20 pictures was used in Experiment 5, the no-naming condition provides a replication of Experiment 1. When the results from this condition were combined with those from Experiment 1, the overall mean number of possible and impossible objects correctly recognized on an individual trial was 3.59 and 3.61, respectively (out of 5 in each case). With memory condition (incidental versus intentional) as a between-participants factor and object possibility as a within-participants factor, ANOVA revealed a significant main effect of memory condition, with better recall in the intentional condition than in the incidental condition (3.84 versus 3.37, respectively). The main effect of object possibility and its interaction with memory condition were both very small and insignificant, $F(1, 118) = 0.18$ and .07, respectively. With the results of 120 participants contributing to this analysis, there is protection against a Type II error in relation to these null results (see the discussion of effect size, power, and sample size in the context of Experiment 1).

Discussion

Object possibility enhanced recognition memory, but only when objects were named at presentation. Hearing an object named at presentation appears to have increased the likelihood that a description of its global, 3D shape was derived. This description then supported recognition memory, so that naming enhanced memory for possible objects only. This finding reinforces the idea that names have privileged links with descriptions of global, 3D shape, and contradicts the view that recognition memory cannot be supported by such descriptions (see Cooper & Schacter 1992, for a review). Therefore, as Cooper et al. (1992b, p. 54) propose, recognition memory, like object decision, can be supported by descriptions of global, 3D shape when the original encoding task encourages the derivation of these descriptions (see also, Schacter et al., 1990).

GENERAL DISCUSSION

The present study has compared peoples memory for pictures of possible and impossible objects and provided evidence that object names are closely linked with representations of global, 3D shape. When people learned single-syllable non-words as names (count nouns) for pictures of objects, they did so more easily for structurally possible objects than for structurally impossible objects (Experiments 2–4). This effect was independent of the memorability and distinctiveness of the individual items. Given that the non-words were randomly assigned to the pictures, the differential ease with which names were learned to possible and impossible objects appears to reflect the differential memorability of different types of object–name association. More specifically, the results indicate that object names have close links with the descriptions of global, 3D shape that are recoverable from structurally possible objects but not from structurally impossible objects.

Whereas in Experiments 2 and 3 participants memory for picture–name associations was tested by presenting a picture and asking for the corresponding name, in Experiment 4 it was tested by presenting a name and asking for the corresponding picture to be selected from the pool. In each case, name learning was easier for pictures of possible objects, suggesting some generality to the processes being revealed.

Experiment 3 showed that the associations learned in Experiment 2 were retained, albeit imperfectly, for 2 months, even though participants had no expectation that their memory for the associations would be tested again. Had the learning been confined to the period of Experiment 2, it might have been seen to reflect special purpose mechanisms, specifically and temporarily established for the experimental task. Instead, however, it seems that memory for the associations reflected processes supporting the long-term learning of object names. The impact of object possibility implies, therefore, that descriptions of global, 3–D shape normally contribute to such long-term learning in the real world.

Experiments 1 and 5 indicated that the derivation of a description of the global, 3D shape of an object is not obligatory. When the encoding task does not draw peoples attention to this aspect of an object, object possibility need not have an effect on recognition memory, even when remembering is intentional. However, when another person is heard to name the object at presentation, then object possibility has an effect on recognition memory, indicating two things. First, hearing the name of an object increases the probability that a description of its global shape will be derived. Second, explicit recognition memory for the object can benefit from the availability of such a description.

The results of Experiments 1 and 5 are consistent with previous work comparing memory for possible and impossible objects. Thus, priming in the object decision task, seen as reflecting the derivation of a structural description, has been observed only when the encoding task has drawn attention to the objects global shape (Schacter et al., 1990). A strong prediction from the present study is that hearing objects named at presentation will provide an encoding context that gives rise to priming in the object decision task. In addition, object possibility has occasionally been observed to influence recognition. This has occurred in situations where the encoding task has drawn attention to the global shape of the objects and where, as a consequence, priming of object decisions has been observed (Cooper et al., 1992b; Schacter & Cooper, 1993; Schacter et al., 1990; Schacter et al., 1991a). The results of Experiments 1 and 5 also indicate that a description of an objects global shape will influence recognition memory when attention is drawn to that aspect of the object during the study phase. Hearing someone else name an object appears to serve this purpose.

Boucart and Humphreys (1992) and Boucart, Humphreys, and Lorenceau (1995) have provided evidence for a close association between attending to the global form of a pictured object and object identification. They demonstrate that object identification occurs automatically whenever visual attention is directed at the global form of an object. This happens, for example, when participants judge whether two successively presented pictures depict objects having the same global shape or the same general orientation in the picture plane. Object identification does not occur automatically when participants attend to local features of the pictures, as when they judge whether two pictures have been drawn with the same colour of line. Boucart et al. (Boucart & Humphreys, 1992; Boucart et al., 1995) conclude that attending to the global form of a stimulus is a sufficient condition for activating the stored object representations mediating object identification. Extending these ideas to the present study, we would suggest that hearing someone name an object will encourage attention to be directed globally, at the overall configuration of a figure (i.e., with attention zoomed-out to just the right degree), because this allows the types of representation most supportive of object categorization to be encoded. We predict, therefore, that object naming will cause attention to be broadly spread in order to simultaneously embrace the external contours (envelope) of a pictured object.

There is other evidence indicating that the derivation of object-based descriptions of 3D shape is not obligatory, but requires the encoding task to direct attention appropriately. In a study examining the role of attention in perceptual constancy, Epstein and Lovitts (1985) have shown that for a post-constancy representation of an objects shape to be derived, it is not sufficient for a person to look at the object, even if this involves close inspection (as is needed, for example, to count the number of small marks along its principal axis). However, a post-constancy description of shape is derived when people are told that their recognition memory for each object will be tested and that study-test changes in the objects orientation in depth will need to be taken into account. In other words, a post-constancy description of shape is derived when it is explained that the representation on which the recognition decision is to be made is a viewpoint-independent representation of object shape. A prediction from the present study would be that naming a shape will increase the likelihood that a post-constancy description is derived. One final point worth making in the context of this work is that Epstein and Lovitts employed recognition memory as the dependent variable, and so their results provide further evidence that viewpoint-independent descriptions of object shape can contribute to explicit recognition memory. These results make it difficult to defend either the claim that implicit and explicit memory draw on separate representations, or the claim that explicit recognition memory for objects cannot draw on the types of description of object shape that mediate priming in the object decision task. Instead, it seems that whereas object decision relies exclusively on a representation of an objects global, 3D structure, recognition memory can utilize these and other representations. The other representations appear to be equivalent for possible and impossible objects, and so must involve more localized object features. Judging from previous work they also seem to preserve information about parity and size, and are assumed to preserve objects surface features, such as colour (Biederman & Cooper, 1992; Cooper, 1994; Cooper & Schacter, 1992; Cooper et al., 1992b).

Barbara Landau and her colleagues (see Landau, 1994; Landau et al., 1998) have shown that labelling an object with a count noun draws attention to its shape, with the effect that names are extended to novel objects on the basis of their shape. This has proved to be quite a specific effect, since it can be replaced by a bias towards extending names on the basis of material and surface properties if a standard object is labelled with a non-word in the guise of an adjective (e.g., “This is a daxy one”, “Which of these is a daxy one?”). Of course, in order to create a bias to respond according to the material and surface properties of an object, it is important that these properties are clearly discriminable. If they are not, then there is little alternative to shape as a basis for categorization and name extension.

It would have been valuable to further explore the links between object representations and verbal labels by examining the interaction between object possibility and type of verbal label assigned to a picture (count noun versus adjective). The effects of object possibility would have been expected to be much less evident, if evident at all, for the adjective labels. Unfortunately, although simple line drawings can depict object shape very effectively via edge-based features, and are an ideal medium for depicting impossible objects, they are much less appropriate for depicting material and surface properties. Therefore, in order to examine the interaction between object possibility and type of verbal label, it will be necessary to present objects in a different way, but in a way that is still capable of depicting impossible, as well as possible, objects.

Two other lines of research also encourage the view that there is a close link between representations concerned exclusively with object shape and representations of object name. One line of research has investigated the visual representations utilized by people when they combine visual images of two recently presented pictures in order to identify an emergent form (Brandimonte, Hitch, & Bishop, 1992; Hitch, Brandimonte, & Walker, 1995; Walker, Hitch, Dewhurst, Whiteley, & Brandimonte, 1997). Two types of visual representation have been shown to support image combination. The first is a relatively literal representation preserving information about the surface properties of an object (e.g., colour and texture) as well as its shape. The second is a more abstract representation concerned solely with object shape. Of particular relevance in the context of the present study is the observation that naming the to-be-combined objects at presentation causes people to rely on the second type of representation to discover the emergent form (Brandimonte et al., 1992; Hitch et al., 1995; Walker et al., 1997).

The second line of investigation is concerned with the manner in which young children depict objects in their drawings. It has been observed that naming a familiar object increases the likelihood that children, when drawing the object, will depict parts that are currently out of view (Bremner & Moore, 1984; Lewis, Russell, & Berridge, 1993) Indeed, Bremner and Moore found that naming the object had the same effect on childrens drawings as allowing them prior inspection of the object from a variety of angles, something that would be expected to support the derivation of a global, viewpoint independent description of the object. Bremner and Moore, and Lewis et al. propose that naming had this effect because viewpoint-independent categorical representations of objects are tagged with their category names. More recently, Walker, Cooper, and Bremner (submitted) have demonstrated that when 5- and 6-year-old children hear the experimenter name a novel object with a novel name ("This is a dax") their drawings of the object are more likely to include a hidden part. Walker et al. argue that this happens because names are directly linked to viewpoint-independent representations of the particular object being drawn, and these representations incorporate information about all the important parts of an object, including any that are currently out of view.

Other researchers have presented strong arguments for the idea that representation of an objects shape is linked to representation of its name only indirectly, via representation of its semantic features (for reviews, see Bruce & Humphreys, 1994, and Humphreys, Lamote, & Lloyd-Jones, 1995). For example, the Interactive Activation and Competition (IAC) approach to object processing (Humphreys et al., 1995) assumes a hierarchical organization across these different domains of representation (pools of representational units), with structural units being activated before semantic units, which in turn are activated before name units. Hence, it is argued that semantic knowledge needs to be activated for object naming to be possible, and evidence from neuropsychology is recruited to support this argument. However, despite its hierarchical organization, the IAC model assumes a direct mapping of sorts between structural units and name units, because semantic units are relatively directly linked to structural units to reflect the fact that for many object categories category members are structurally similar to each other. Thus, in the graphic illustration of the IAC model, Humphreys et al. show individual structural units mapping on to individual semantic units, which in turn map on to individual name units.

The objects depicted in the pictures used in the present study were designed to be largely devoid of semantic features, and yet people were able to learn the associations between object shape and object name. One way of reconciling this with the hierarchical organization of the three representational domains would be to argue that the particular circumstances of the present study caused participants to draw on aspects of the visual cognitive system that are not normally involved in object processing. However, since it is not uncommon for people to learn object names before they have an appreciation of the functional and associative significance of the objects, the circumstances of the present study may not be especially unusual. A second way of reconciling the semantically impoverished nature of the objects used here with models of object processing would be to assume that information flows through successive representational domains in cascade, rather than in a discrete fashion where processing in one domain does not begin until processing in preceding domains is complete. Having made this assumption in relation to their IAC model, Humphreys et al. indicate that it is not necessary for all semantic knowledge to be retrieved in order for naming to take place. So that, for example, for an object sharing very few structural features with other members of its category, there may be very little semantic activation prior to naming, giving the impression that object naming is being directly driven by object structure. On this basis, the novel objects used in the present study qualify as candidates for relatively direct naming since, by definition, they are structurally dissimilar from any objects in existing categories. Thus, to propose that structural descriptions and name codes can be reciprocally and closely linked may not be incompatible with hierarchical models of object processing, like IAC, in which semantic representations are able to intervene.

NOTES

(1) Enns (1992) discusses the visual processes that recover the global, 3D structure of objects from line drawings. Refering to Enns and Rensink' s PRISM model (1991), he argues that early visual processes derive local estimates for the segmentation of object parts (from T-junctions) and for the 3D orientations of surfaces that meet at convex and concave corners (from arrow- and Y-junctions). He proposes that these estimates can be derived quickly and in parallel across the visual field provided there is a relaxation of the strict requirements for *validity* that models of early visual processing conventionally demand. For example, the crossbar of a T-junction might always be interpreted initially as a boundary edge, even though it could arise from the accidental alignment of a surface with the line of sight. To deal with the occasional errors of interpretation arising from relaxing the demand for validity, later visual processes are thought to complete a consistency check across all regions to determine if, for example, surfaces are being assigned the same orientation on the basis of different local features. Some of the evidence reviewed by Enns to support his proposals comes from peoples responses to line drawings of objects that yield either consistent or inconsistent sets of local 3D interpretations, like the pictures of structurally possible and impossible objects employed in the present study. Of particular significance in the present context, Enns approach assumes there are processes sensitive to the consistency (possibility) of the 3D interpretations being recovered from different parts of an object. On this basis, therefore, investigating the effects of object possibility should benefit our understanding of basic visual processes supporting object perception. The benefits should extend beyond the specifics of the object decision task.

(2) Ratcliff and McKoon (1995), and Williams and Tarr (1997) have recently questioned the idea that priming in the object decision task reflects the influence of representations of global, 3D shape that are recoverable for possible objects only. Most notably, Ratcliff and McKoon (1995) propose that the typical pattern of results from the object decision task arises from the combined effects of two influences. First, from a tendency for previously seen objects (whether possible or impossible) to be judged "possible". And second, from a tendency to remember explicitly how a previously seen object was classified at the time (as possible or impossible) and then to re-adopt this classification as the judgement in the object decision task. Whereas for possible objects both influences encourage a "possible" response, for impossible objects they work in opposition. Ratcliff and McKoon explain the apparent absence of priming for impossible objects by arguing that these two opposing influences just cancel each other out. Although the present study accepts the main assumption underlying the original interpretation of the priming effect in the object decision task (i.e., that a representation of an objects global, 3D shape is recoverable for possible objects only), it is not dependent on the correct interpretation of this effect, which might well be task specific. Nevertheless, it is perhaps worth pointing out that the evidence Ratcliff and McKoon provide for their argument is not without its problems. For example, concerns exist regarding the appropriateness of the pictures used in their experiments (see Williams & Tarr, 1997), and about what their participants explicitly remembered about the pictures from the study phase of the object decision task. When Ratcliff and McKoon asked a group of people to judge whether each of their pictures depicted a possible or an impossible object, and gave them unrestricted viewing in order

to arrive at a decision, their performance was unimpressive. Only 78% agreed that the possible objects were possible, and only 76% agreed that the impossible objects were impossible. One can only wonder how many participants in the first phase of Ratcliff and McKoon's experiments spontaneously became aware of the possible/impossible status of each picture when they were concentrating on judging the overall orientation of each object and had not been informed about structural possibility as an aspect of the drawings. Uncertainty about the status of each picture is heightened by the very low levels of performance observed in the object decision task itself. For example, the participants in Ratcliff and McKoon's sixth experiment seemed unable to decide that the impossible pictures were impossible, their responses being fairly evenly split across the "possible" and "impossible" categories. With these reservations, it is not clear just what Ratcliff and McKoon's participants were explicitly remembering about the pictures from the study phase. Not only is it unclear how they interpreted each picture at study, it is also unclear if these interpretations were then remembered. Despite the important role that explicit memory for the study pictures plays in their proposals, Ratcliff and McKoon relied on indirect and unconfirmed attempts to manipulate explicit remembering. And indeed, as a counter to Ratcliff and McKoon's proposals, Schacter and Cooper (1995) make much of the fact that in their own experiments explicit memory for the study pictures varied significantly across conditions, yet the pattern of priming effects in the object decision task remained unchanged.

Williams and Tarr (1997) endeavoured to clarify and extend the concept of bias in the object decision task. They offer a different explanation for the priming that occurs, but in doing so they too deny any role for a unitary representation of a possible objects global, 3D shape. Instead, they propose that people performing the object decision task analyse the different portions of an object separately from each other. Priming in the task is then seen to reflect facilitated encoding of structurally possible portions when they are re-encountered by the participant. By arguing that priming is confined to possible portions (because it is based on the recovery of coherent 3D descriptions) their approach is similar to the original explanation of why priming in the object decision is restricted to possible objects (see Cooper & Schacter, 1992). The fundamental difference between the two approaches revolves around the issue of whether a whole object can sometimes be treated as a portion in the Williams and Tarr sense. Various factors might determine the scale at which structural portions are segregated, and the complexity of an object might be one of these. For objects that are complex (perhaps because they comprise a larger number of constituent geons) it might be difficult to sustain analysis at a global level. This also might be the case when participants have to distinguish between possible and impossible objects that have the same global configuration and differ only in the structural possibility of an individual portion/geon (see Williams & Tarr, 1997). We would contend that the possible objects devised for the present study were simple enough for processing to be initiated and sustained at a global level. If so, then, as Enns (1992) points out, a discrepant 3D feature in a line drawing of an object can be interpreted as discrepant only in the context of the interpretations of other, neighbouring 3D features. For a relatively simple object this would mean that the whole object is likely to qualify as a portion in the Williams and Tarr sense. Further work is needed to clarify the factors determining the different levels at which objects are attended and represented, and the scale at which possibility/impossibility is interpreted. At this stage, however, we believe that interpretations of structural possibility can emerge in relation to representations of the 3D shape of whole objects.

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